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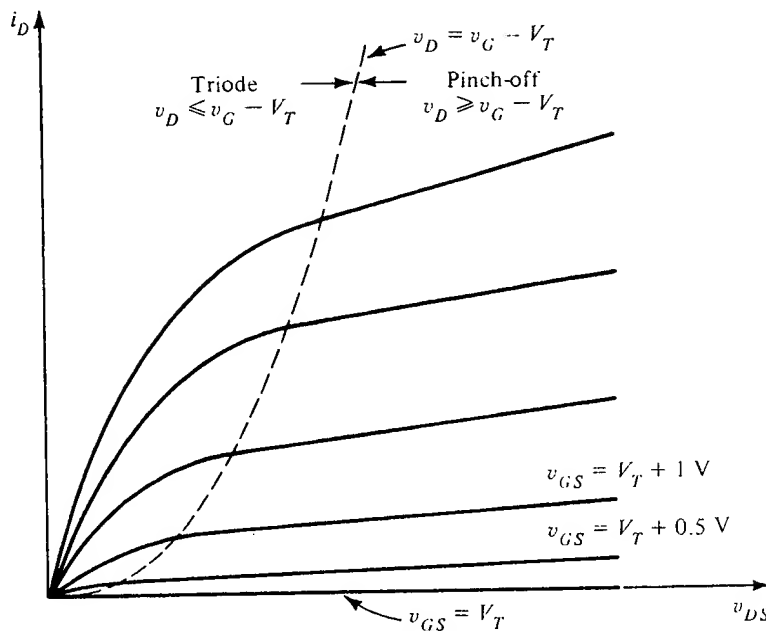


Fig. 8.15 Actual characteristics of *n*-channel MOSFET, illustrating the finite nonzero slope in the pinch-off region. Note that the slope increases with the current level in the device. Thus the output resistance r_o is inversely proportional to the bias current I_D .

In the following we shall study two popular biasing arrangements for enhancement MOSFETs.

A First Biasing Scheme

Figure 8.16 shows our first biasing arrangement; although it looks identical to that used for biasing JFETs and depletion-type MOSFETs, the principle of operation is some-

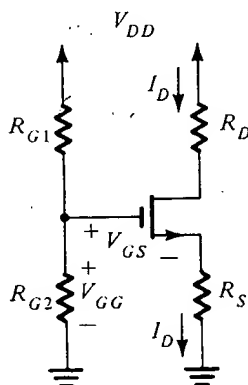


Fig. 8.16 A popular biasing arrangement for enhancement MOS amplifiers.

head on the source points in the direction of normal current flow. Finally, note that the symbol for the p -channel device is drawn with the source up, which makes it conform with our circuit-drawing convention of currents flowing from top to bottom.

Recapitulation

Consider Fig. 8.14. For the n -channel enhancement device shown in the figure to conduct, v_{GS} has to be positive and greater than V_T . The device will operate in the pinch-off or active region if the drain voltage v_D is more positive than the gate voltage v_G by

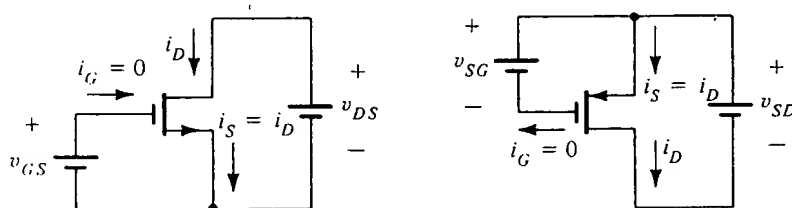


Fig. 8.14 Normal current flow directions and voltage polarities in enhancement MOS transistors.

at least $-V_T$. That is, the device will still be in pinch-off even if the drain voltage is lower than that of the gate by V_T volts. If the drain voltage is further reduced, the device gets out of pinch-off and goes into the triode region.

For the p -channel device to conduct, the source has to be made more positive than the gate by at least $|V_T|$ volts; that is, $v_{SG} \geq |V_T|$. The device will be in pinch-off as long as the drain voltage is lower than that of the gate, or even if it is higher than that of the gate by at most $|V_T|$. If v_D is increased more than $|V_T|$ volts above v_G , the device leaves pinch-off and enters the triode region.

Of course, the pinch-off region is the one suitable for amplifier application. Switching applications make use of the cutoff region and the triode region.

Finally, we should point out that real devices display a finite output resistance when operated in the pinch-off region. Figure 8.15 shows the i_D - v_{DS} characteristics of an n -channel MOS transistor of the enhancement type. In pinch-off the characteristic curves show finite slope that increases with the current level in the device.

EXERCISE

- 8.2 Consider an enhancement NMOS transistor with $V_T = 2$ V which conducts a current $i_D = 1$ mA when $v_{GS} = v_{DS} = 3$ V. What is the value of i_D for $v_{GS} = 4$ V and $v_{DS} = 5$ V? (Assume that in pinch-off the device acts as a current source.) Also calculate the value of the drain-to-source resistance r_{DS} for small v_{DS} and $v_{GS} = 4$ V.

Ans. 4 mA; 500 Ω

8.3 BIASING THE ENHANCEMENT MOSFET

As mentioned before, the first step in the design of a transistor amplifier involves establishing a stable and predictable dc operating point inside the active region of operation.